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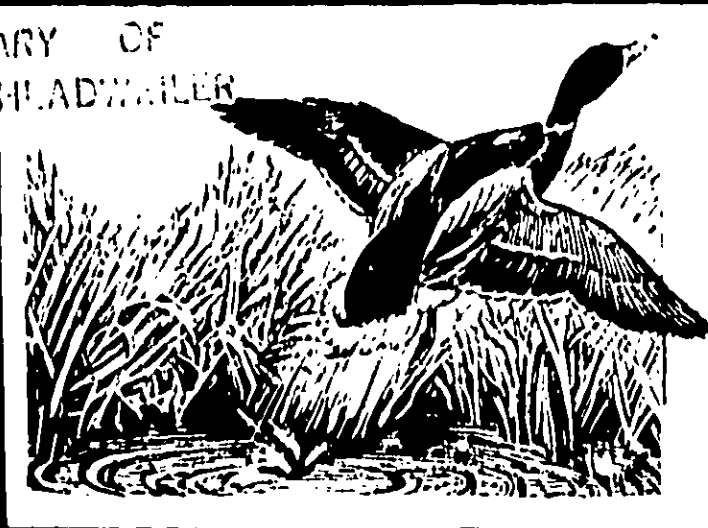

A LITERATURE REVIEW ON VEGETATION MAPPING IN WATERFOWL BIOLOGY

G. G. W. Robinson

August 1971

BUREAU OF SPORT FISHERIES AND WILDLIFE
AND COOPERATIVE WILDLIFE RESEARCH UNIT

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FOREWORD

Record numbers of sportsmen hunted waterfowl in the U. S. A. in 1970. Also, interest in the sport hunting of wildfowl in Canada and Mexico is increasing. Consequently, waterfowl managers have been issued the demanding challenge of satisfying this increasing demand for waterfowl which must be produced from a resource base that is gradually being eroded because of agricultural development, urbanization, water pollution, and other factors.

This challenge has been met, at least for the time being, thanks to a serendipitous weather cycle, development of effective fact-finding and regulatory systems, and protection and improvement of some critical waterfowl habitats. Yet those persons who are most familiar with North America's waterfowl management system are the most apprehensive of our capacity to deal effectively with the next drought, a sudden increase in demand for cultivated land, or with any one of several other crises which could unexpectedly occur.

Waterfowl managers, like other wildlife biologists, have been slow in applying and profiting from modern techniques in vegetation mapping involving aerial photointerpretation, stereoscopy, and color photography. In this literature review on vegetation mapping in waterfowl biology, Gary Robinson has produced an extremely useful summary of the subject for the waterfowl management practitioner. He has summarized relevant literature from a great many sources which are not readily available to the man in the field. Due to his summary, I am confident that the rate of adoption of these helpful techniques by waterfowl biologists will be accelerated. Hopefully, too, the waterfowl manager will be encouraged to accept more readily space-age techniques, such as multispectral photography and electronic scanning which are now being developed within other scientific communities, than he has the normal tools of vegetation mapping.

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A LITERATURE REVIEW ON VEGETATION MAPPING IN WATERFOWL BIOLOGY

ABSTRACT

The loss of waterfowl habitat due to increasing human population and human needs has reached a critical point. It is, therefore, imperative that the remaining wetland areas be managed for maximum production if ducks, geese, swans, and other aquatic wildlife are to be part of the original aquatic fauna. Although there is an expressed need for vegetation mapping in wildlife management, this technique is little used because aerial photographs are cheaper, faster, and more accurate than ground survey methods alone. However, large-scale vegetation maps allow the wetland manager to foresee impending changes and form better development plans. For purposes of intensive wetland management, good vegetation maps prepared by specially trained and objective research personnel are a necessity.

INTRODUCTION

Continued drainage and industrial encroachment on the remnants of natural waterfowl breeding and feeding grounds in the United States have created a serious problem in the maintenance of our continental supply of waterfowl (Uhler 1956). It must be kept in mind that, as human populations continue to expand, total wetland acreages will become smaller, and the job of preserving and developing wetlands for wildlife will become correspondingly greater and more expensive (Shaw and Fredine 1956).

Therefore, it is extremely important that measures be developed promptly for replacing these recently destroyed waterfowl habitats through construction of new breeding and wintering grounds for waterfowl, on readily available sites which are not being profitably utilized by man (Uhler 1956). It is equally important that methods be devised for the improvement of existing waterfowl areas. Nelson (1954) felt the future of waterfowl on this continent hinged on the success of habitat restoration and new wetland development.

Uhler (1944) found the attractiveness of natural feeding and breeding grounds for waterfowl to be primarily dependent on the type and condition of vegetation predominating in such areas. Griffith (1964) believed that breeding grounds were more than just water and cover; they must be of particular types and in particular combinations to suit the varying needs of the many waterfowl species. A thorough understanding of the habits and requirements of waterfowl, and of environmental forces acting upon them, is necessary if such areas are to be managed to the best advantage for the purpose for which they were created (Williams and Marshall 1938).

Kuchler (1953a) stressed intelligent use of the land, and that optimum results require a detailed knowledge of what and how much the land can produce under given circumstances. He concluded that a detailed vegetation map would not only reveal present conditions of the vegetation but potential land use at its optimum as well; and it would save a planner innumerable time-consuming trips into the field, appreciably reducing both time and expense.

The use of cover mapping as an essential tool in the field of wildlife management has been discussed by many authors (Dalke 1942, Graham 1945, Alexander 1959, and Mosby 1963). Such a map needs to be more than just a cover map because it should indicate other wildlife requirements furnished by the habitat (Alexander 1959). He therefore suggested that the name "habitat map" was more appropriate. However, Davis (1960) felt the word "habitat" and its concept, when employed as a discrete term in many of the biological sciences, has become both vague and restricted during the recent expansion and fragmentation of these sciences. Davis further proposed that habitats do not necessarily contain organisms or a particular organism and, consequently, there are both occupied and unoccupied habitats. Therefore the criteria for the habitat concept are distinct from those of the term and concept of environment.

The phrase "evaluation of wildlife habitat," as used by Mosby (1963), implies both intensive and extensive efforts to estimate or appraise the value of various segments of the environment as they relate to a given animal population. Generally, he feels vegetation is the most important aspect of the environment for most forms of game animals.

Kuchler (1967), in discussing terminology, felt that if a map is entitled *Vegetation Map of Jefferson County* then the logical conclusion is that it portrays the vegetation. If, however, the effects of climate, soil, water, topography, or other environmental features are introduced, then the map ceases to be a vegetation map *sensu stricto*. If the title does not lend itself to an adequate description, a subtitle is used to elaborate the title and thus lead the reader in the right direction.

CRITERIA FOR MAPPING

GENERAL

The purpose of a vegetation map determines the content and character of the map and these, in turn, determine the method to be used in preparing the map (Kuchler 1967). When the purpose of the map is clearly established and the desired content and character of the map have been determined, then and only then, Kuchler (1967) believes, can the mapper select an appropriate mapping method. Vegetation maps satisfy two groups of interests: (1) they are inventories of plant communities existing at a given time and place; they show the areal distribution of vegetation types and thereby the extent of what is valuable and desirable, and the relation of topography to the distribution of vegetation; and (2) through proper use and interpretation of the vegetation map it is possible to plan future action with regard to optimal land use, i.e., the best adaptation of land use to the requirements of the people at any given period, and also qualitative and quantitative maxima of production without damage to the soil and water economy of the landscape (Kuchler 1953a). The immediate usefulness of a vegetation map, Kuchler (1953a) concluded rests on the fact that it shows the distributional aspects of vegetation and that plants, and more especially plant communities, indicate the complex features of climate and soil.

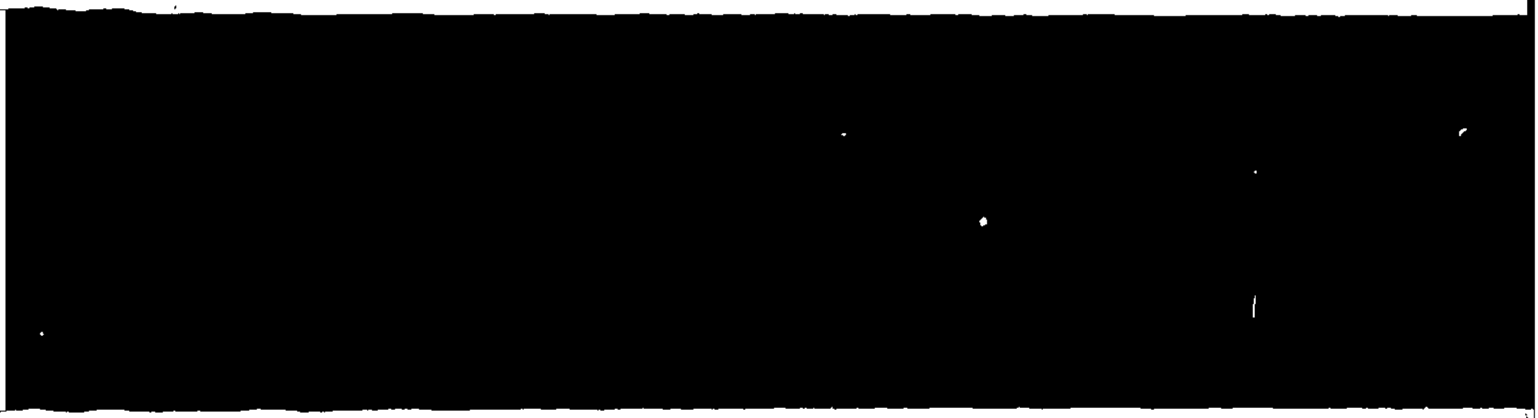
Kuchler (1967) found the value of the earlier Forest Service vegetation maps to be debatable, but felt these maps were expressions of the trial-and-error approach. He felt it was to the credit of the Forest Service that it continued to map and raise its standards. More recently, the Bureau of Land Management, the Soil Conservation Service, fish and wildlife agencies, river basin authorities, planning agencies, state geological surveys, the National Park Service, and others have realized the need for vegetation maps of plant communities in the areas under their jurisdiction (Kuchler 1967). Wilson and Berard (1952) felt wildlife biologists were unaware of the extent to which ecological principles could be applied to interpretation of aerial photographs for cover mapping. Acquired knowledge and technique in the use of photographic interpretation does not yet exist in wildlife management; in fact they (Wilson and Berard) found the forester, as indicated by recent methods, is more rapidly approaching the use of certain ecological principles of value to the wildlife profession in forested areas than is the wildlife biologist.

VEGETATION CLASSIFICATION

Hope has been expressed that a uniform method of vegetation mapping would be developed so that various areas would be comparable at corresponding degrees of detail (Graham 1945, Kuchler 1951,1956, and Alexander 1959). Graham (1945) indicated that two viewpoints were common. The first and older idea grew from the matter-of-fact assumption that the objective of cover mapping had been satisfied when the existing cover was classified and mapped to show the predominant plants on the ground. Unfortunately such maps give no indication of the origin of the types. The second and more recent viewpoint, in contrast to the purely descriptive procedure, recognizes that conditions continually change, that some types were transient and others were more stable, and that the sequence of ecological change proceeded in an orderly manner. Later Kuchler (1956) described two more recognizable attitudes among authors of vegetation maps. The first revealed a groping toward a clearer recognition of what was involved in making vegetation maps for a given purpose. Lack of background often resulted in inferior maps, and the author might or might not have been aware of these weaknesses. The other attitude was that of the author who "believes" in the superiority of his "system" and applies it for all purposes. Kuchler (1951) found it astonishing that so many vegetation maps had been published which more or less ignored the classifications various authorities had proposed.

The following discussion of vegetation classification was taken from Kuchler (1951). "The basic ideas underlying all classifications of vegetation as we find them on maps are very few in number. The complexity of the world's vegetation, the great variety of the purposes, the incalculable personal elements, the problems of definition, the historical and environmental aspects, all would lead one to believe that classifications can be counted in scores. A closer examination reveals, however, that all vegetation maps are based on classifications which rest on four basic concepts only. The many vegetation maps are only variations of the same themes and the great variety among the existing maps is due to the fact that these themes can be employed singly or in combination and the combinations are almost infinite in number. The four basic themes are: 1. regional, 2. physiognomic, 3. floristic, and 4. ecological."

The Regional Approach — The differentiation of vegetation into regional units indicating the areal affinities of the flora. This approach is relatively rare.



The Physiognomic Approach — The important conclusions to which the physiognomic approach may lead are the value for comparative studies and the relative ease with which the pertinent data can be compiled. The physiognomic method enormously extends the use of vegetation maps as *it does not presuppose a taxonomic knowledge of* the vegetation.

The Floristic Approach — The floristic composition is the basis of this procedure and the units shown on the maps are plant communities characterized by certain species. A disadvantage of the floristic approach to mapping is the general lack of familiarity with the taxonomy of most regions.

The Ecological Approach — In itself, the recording of environmental aspects certainly is not mapping vegetation; but climate, soil, and other features have such a strong effect on the distribution of species and plant communities that attempts continue to incorporate the character of the environment into the map.

Kadlec (1960) used a system of cover mapping, primarily species of emergent cover, based on physiognomy. He felt an inspection of the data on species composition indicated no valid reason, from a waterfowl management standpoint, to create so many types. *His statements seem to* indicate a different interpretation of physiognomy than described by Kuchler (1951).

The ecological approach *seems to be the most* popular and useful in wildlife management. Dalke (1937) correlated the major plant associations into an orderly arrangement of ecological succession to provide a working basis for cover mapping. Provost (1947) felt a discussion of marsh cover is rendered meaningless if the emergent vegetation is considered static. Wildlife researchers have developed classifications for particular areas based generally upon ecological succession, such as Guthe and McMurry (1930) and Wight (1934) for southern Michigan, Dalke (1937) for Connecticut and Missouri, Graham (1945) for Michigan, MacConnell (1957) for Massachusetts, and Alexander (1959) for central New York.

If an author wishes to prepare an ecological vegetation map, it is best for him to inspect a large number of such maps, especially those that contain the type of information in which he is interested (Kuchler 1956).

VEGETATION MAPPING

DETAIL REQUIRED

Mosby (1963) believed the greatest problem encountered in cover mapping relates to the amount of detail to include. No definite answer can be given to this question because vegetative *detail varies greatly, depending on* (1) use of the map; (2) the area, or acreage; (3) time available for mapping; (4) principal animal species under consideration (*i.e.*, sedentary small rodents or migratory caribou); and (5) related factors. In general, the more intensive the management or study, the more detailed will be the cover types employed (Dalke 1941). Mosby (1963) cited Graham's (1945) system of cover mapping based on ecological succession as one that may be expanded to include as much detail as may be required, or abbreviated for extensive cover mapping. Graham's types are divided into three principal groups depending upon their origin and character: upland types, lowland types developed from water areas, and transition types. either highland or lowland. In explaining his system Graham stated that by using exponential and subletters with the appropriate capital letter, both physiographic and disturbance conditions may be represented; by adding exponential symbols to represent predominant species, size, and degree of stocking, the specific composition of a type may be indicated. *He felt this system lent itself to any* degree of detail required.

The minimum size of cover types recorded on the map may vary considerably. Dalke (1941) found that on farm-wildlife areas, it is frequently desirable to indicate cover types as small as two acres, while in large timbered areas, types are rarely that small except in the case of openings.

WETLAND MAPPING

Martin et al. (1953) developed a wetland classification system which was adopted by the Bureau of Sport Fisheries and Wildlife. Using this classification, Shaw and Fredine (1956) surveyed the wetlands of the United States. This classification has been followed for several years by biologists who found it useful in appraising general wetland conditions throughout the country (Stewart and Kantrud 1969). For purposes of research investigations, land acquisition, and more intensive management programs Stewart and Kantrud (1969) thought a classification system more closely oriented with regional and local variations in the environment was needed. To establish a sound basis for a general wetland classification system for North America, more detailed ecological investigations of wetlands in each of the major biogeographical regions will be required.

Kuchler (1967) stressed that large-scale mapping is needed for detailed maps of relatively small areas and for experimentation. Large-scale vegetation maps are needed most in ecological studies, whether basic or applied to silviculture, range management, or land use planning. He concludes that whatever method the mapper selects, he must avoid premature generalizations and must not project earlier concepts into his observations.

AERIAL PHOTOGRAPHS

There are several reasons why vegetation mapping progressed so rapidly during the midcentury period, and not the least of these were the fine technological devices that permitted workers to do things that seemed unthinkable a generation or two ago (Kuchler 1967). He contended that, from the viewpoint of the vegetation mapper, the most useful and significant was aerial photography.

Various field methods of vegetation mapping using aerial photographs have been described (Wilson 1922, Dalke 1937 and 1941, Trump and Hendrickson 1949, Wilson and Berard 1952, Nelson 1954, Tanner 1955, Alexander 1955, Viktorov, Vostokova, and Vyshivkin 1959, Kuchler 1967, and Uhler and McGilvery 1969).

Although experiments in aerial photography date back to the last century, it was not until World War I that any great advances were made in this field (Leedy, 1948). In 1919, Thelen stated that the possibility of producing accurate topographic maps from photographs has been appreciated for many years, and that the camera had been used for limited topographic surveys in India, France, and Italy, and almost exclusively in Canada. He felt if aerial maps were made recurrently, they would afford the best possible permanent record of changes and improvements in the forests. Wilson (1920) predicted that we were still in the very infancy of this work and that, for mapping purposes alone, photographs were far superior both in detail and accuracy to ground work.

Europe continues to lead the world in vegetation mapping, and, as this field grows in importance on all the continents, the need for vegetation maps in the United States becomes more and more urgent . . . (Kuchler 1953b). Leedy's (1953) correspondence with wildlife biologists in Denmark and England revealed that relatively little use was being made of aerial photography in connection with wildlife work in those countries. It appears that wildlife biologists throughout the world are slow to realize the potential of vegetation mapping and the use of aerial photographs.

TYPES OF AERIAL PHOTOGRAPHS

Leedy (1948) explained the two main types of aerial photographs, the oblique and the vertical. "Vertical photographs are those made when the axis of the camera is kept as nearly at right angles to the earth's surface as possible. Oblique photos are those made with the optical axis of the camera at an angle to the vertical. High obliques are made at a high angle to the vertical so as to show the horizon, while those made at a lower angle in which the horizon is not shown are known as low obliques."

Composite aerial photographs are made with cameras having one principal lens and two or more surrounding and oblique lenses (Leedy 1948). The resulting photographs are rectified or transformed by means of a special projection printing machine so as to permit their assemblage as verticals with the same scale.

A mosaic, explains Leedy (1948), consists of several overlapping vertical photographs joined together. Uncontrolled mosaics may be made simply by matching detail in the overlap or along the borders of prints. This type of mosaic gives a good pictorial effect of the ground, but may contain a considerable number of errors in scale and direction. Controlled mosaics are those in which several photographs are oriented by means of points along the line of flight and adjusted on previously selected ground points. Such mosaics are more accurate.

Dalke (1941) felt that where available, aerial photographs, either as contact prints or mosaics, provided the best and most accurate base maps. These would be vertical photographs. Oblique photos are effective for illustrative purposes in that they provide a sweeping view in a more familiar perspective (Leedy 1948). He warns, however, that unlike vertical photos having scales fairly uniform on any given print, the scale of an oblique decreases in geometric progression from foreground to background.

Leedy (1948) suggested that aerial photographs may be obtained from governmental and private agencies; they usually contain data on their margins which aid in their use. Aerial photographs are usually obtainable from the county agricultural agent, U. S. Soil Conservation Service, the A.A.A., and the U. S. Army in some cases (Anonymous 1946). For mapping small ponds, Doble and Johnson (1951) found aerial photographs available in most county seats inadequate because of the small scale and the variations in the scale. Kuchler (1967) suggested that photographs be taken for a specific purpose and to avoid aerial photographs which are obsolete. The point at which a photograph becomes too old depends entirely on the situation. This problem does not arise when the photographs are specially taken, preferably according to the instructions of the author. Using single-aerial photographs for land-use classification in the resurvey of southwest Georgia, Aldrich (1953) concluded that the accuracy of the classification depended to a great extent on the accuracy of the photo-interpreter, the age of the photographs used, and the season of the year during which the photographs were taken.

SCALE

The amount of detail that can be shown on a map is mostly a function of the scale (it diminishes with a diminishing scale); and information on a small-scale map is usually more generalized than on a map with a large scale (Kuchler 1967). He cites Molinier's et al. (1951) demonstration of the relation between the scale and usefulness of a vegetation map with maps of the Forest of Sainte Baume. The forest was mapped at five different scales, thus permitting an illustrative comparison. This forest of historic interest is 2 kilometers long and 800 meters wide. The following examples give illustrations of what can be detected on maps of various scales, thereby giving the biologist a choice of what is best for his purpose:

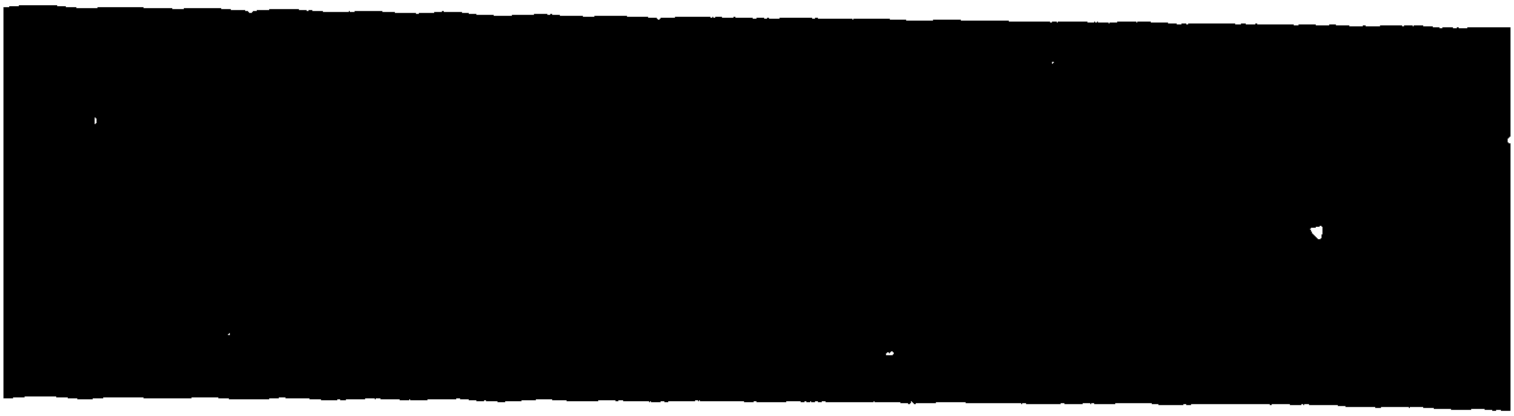
> At the scale of 1:2,000 the map of the forest covers an area 1 meter long and 40 centimeters wide. With this large scale it is possible to show all details, even the exact location of some rare species.
>
> At the scale of 1:5,000 the map is only 40 by 16 centimeters. It is still possible to show most of the details that could be shown at 1:2,000, although it is necessary to use overprinted symbols to avoid cluttering.
>
> At the scale of 1:20,000 the forest measures only 10 by 2 centimeters. Only major aspects of the oak forest and the beech forests can now be shown, without any indication of their density. But all essential features of the vegetation can still be shown.
>
> At the scale of 1:50,000 the forest is no more than 4 by 1.6 centimeters. Only the oak forest and the beech forests can still be distinguished, with perhaps some adjacent communities. The boundaries are only approximate.
>
> At the scale of 1:200,000 the forest is reduced to 10 by 4 millimeters. The boundaries of the two major vegetation groups are now quite inaccurate and the reader can get no more than a general idea of the vegetation.

Molinier concludes that a general idea is inadequate for practical purposes and that the very largest scale (1:2,000) is the most useful for agricultural planning because conditions can sometimes vary within a few meters. This is also true in marsh management, which justifies the use of the largest scale available.

What details are required depends on the individual case; there is no point in having a scale larger than necessary because it needlessly increases the cost (Kuchler 1967). He feels the prospective author of a vegetation map will find it useful to examine a variety of aerial photographs to determine which scale is best adapted to his particular needs. Ultimately, the scale of the aerial photographs is affected by the scale of the planned vegetation map (Kuchler 1967), and a careful author will see to it that the scale of the photographs is at least twice as large as the scale planned for the printed map.

COST

The cost of aerial photographs is only a small fraction of the expenses generally incurred in preparing a vegetation map of the same quality without aerial photographs, *i.e.*, by field surveys only (Kuchler 1967). In 1920, Wilson found that on the ground, in timber, with a party of 10 men using a plane table, 50 square miles a month was the average area covered, as against 200 square miles per day with good photographic weather. At that time, his cost for complete photographic maps turned out to be less than $25 per square mile. Wilson (1922) reported that 12.8 hours were spent getting aerial photographs of 140 square miles for a performance, in terms of useful photos, of 10.8 square miles per hour. A comparison of the two techniques is cited by Wilson and Berard (1952). "Using the line-plot method without aerial photographs, four months were required in which to map the 8,878 acres of Short Mountain Game Refuge, Hampshire County, West Virginia. Employing aerial photographs, random sampling, and pattern mapping, only two months were spent



in mapping the 11,020.8 acres of Seneca State Forest, Pocahontas County, West Virginia. Both areas were mapped during late spring and summer months."

The Bureau of Sport Fisheries and Wildlife, Region 2, had color aerial photographs taken of three national wildlife refuges in 1968. Table 1 shows the cost of the photographs for each of the refuges.

Refuge	Flight cost	Print cost	Total cost	Cost per acre	Acres
Bear River	$1200.00	$1050.00	$5850.00	$0.09	65,000
National Elk	$3250.00	$ 750.00	$4000.00	$0.08	48,000
Monte Vista	$1180.00	$ 120.00	$1600.00	$0.11	14,800

Table 1. Cost of color aerial photographs of the Bear River, National Elk, and Monte Vista National Wildlife Refuges

STEREOSCOPE

Vertical photos with a 60 percent overlap permit the use of a stereoscope for detailed study (Leedy 1948). Stegeman (1939) stressed that wildlife studies are primarily of an ecological nature, and as such the recording of conditions in all three dimensions is necessary to show the relationship of given objects to their environment. For this reason, he felt that two-dimensional pictures even in perfection leave much to be desired. Leedy (1953) and Kuchler (1967) stressed that the usefulness of aerial photographs is so much improved by employing a stereoscope that this is really an essential tool. A single photograph is equivalent to viewing the landscape through one eye (Kuchler 1967). Carneggie (1968) states that the detail seen on very large-scale photos (by viewing stereoscopic images) will enable the photo-interpreter to differentiate plant communities accurately and rapidly (by observation of the species composition, plant height, and density), determine an index of plant vigor, locate sample plots more effectively in the field for conducting more detailed studies, and identify soil surface characteristics, such as crust formation, texture, and rockiness.

COLOR PHOTOGRAPHS

Like all branches of modern technology, photography is rapidly evolving at the present time and perhaps it is not difficult to forecast that the near future will see most vegetative mapping done with the help of aerial color photography (Kuchler 1967). Schulte (1951) found the photo-interpreter of vegetation has a difficult task when asked to identify species of plants recorded on an aerial photograph. The difficulty, he feels, becomes all the more evident when it is realized that plant species cannot always be identified by eyesight even at close range, *e.g.* at 25 feet (scale 1:16 to 1:25), but must be viewed with a hand lens for special minute structures in the flowers or on the leaves. It may not always be necessary, from a management standpoint, to identify to species. Carneggie (1968) pointed out that moisture-tolerant plants, such as sedges (*Carex* sp.) and rushes (*Juncus* sp.), usually occupy marshy habitats and that the photo-interpreter is able to distinguish between sedges and rushes by exploiting color differences between them.

Humans have the capability of discriminating between an almost infinite number of different colors, but at most only a few hundred different shades of gray (Strandberg 1968). Schulte (1951) stated: "In summer when all vegetation is green little advantage is obtained by use of color photography. The resolution of detail and texture patterns are much like that of black and white photographs. Perhaps the greatest advantage of color photography lies in its use for spring and autumn seasonal changes; the time and place are usually very limited especially when the uneven rates of color change and the number of fair days for photography are considered." Carneggie (1968) stated that, given an optimum scale and season of photography, the following types of information can generally be extracted more readily from color photographs than from conventional field investigation: (1) delineating and classifying plant communities and their associated soils; (2) determining species composition and foliage density of the dominant shrubs, grasses, and herbs; (3) determining an index of plant vigor, surface rockiness, and texture, amount of accumulated litter, presence of surface and subsurface moisture; (4) evaluating forage utilization; and (5) locating other features affecting range management including springs, stock-watering sites, salt grounds, fences, canals, noxious plants, rodent concentrations, highly erodible sites, and areas in need of reseeding.

The use of aerial photographs in mapping has advantages as well as disadvantages. For mapping extensive areas some major advantages are (Schultz 1952): (1) the low initial cost of individual photographs, and (2) the great amount of detail available. Considerable help is indirectly obtainable from the photos (Jensen 1947). First, they provide control for the ground observation of species composition through the prior delineation of vegetation elements; and second, they offer a means for expanding the species classification beyond what is actually seen on the ground through observable terrain and vegetational-associated relationships visible both on the ground and from photos. Some major disadvantages are (Schultz 1952): (1) the relatively high cost of reproducing, in quantities, a final map containing the details available on aerial photographs; and (2) the large number of individual aerial photographs needed for coverage of an extensive area which prohibits their direct use on a practical-composite map. Jensen (1947) stated that users of the photo technique should bear in mind that the aerial photos are rarely maps on account of inherent characteristics that cause areas to appear in other than their true sizes and shapes. Chief among these characteristics are: (1) the variation in perspective from vertical at the center of the photos to a degree of obliqueness at their edges; and (2) the variation in distance between subject and camera lens that causes differences in scale whenever the ground is not level.

FINAL MAPPING

SYMBOLS AND PATTERNS

The method of presenting vegetative units and divisions is an important feature of the vegetation map because clarity and legibility of the map depend on it (Kuchler 1967). The primary purpose for using black-and-white patterns or color is to distinguish between the different types of vegetation.

Mosby (1963) cited Wight (1934, 1938), Dalke (1937, 1941), and Graham (1945) as having pointed out the need for using cover map symbols based on ecological succession. Kuchler (1967) suggested that spacing of symbols can be done in two ways. It may be irregular, possibly implying that the position of a symbol on the map corresponds to the actual location in the field. Where numerous stands of a plant community permeate an extensive vegetation type, it is clearer and simpler to have the symbols spaced evenly throughout the area involved. Graham (1945) felt it necessary to adopt symbols to represent the various tree, shrub, and herbaceous species used to characterize types. For uniformity, he suggested, it is desirable for all workers in a locality to use the same species symbols on their maps insofar as possible. Caution must be exercised, however, to avoid expanding the symbols employed to a point where the map becomes unintelligible due to its complexity (Mosby 1963). Kuchler (1967) found that symbols can be given statistical values by varying their character, size, and density (number per unit area).

Additional information, e.g. game ranges, can be superimposed upon a print of an aerial photograph merely by attaching a sheet of drafting acetate containing the desired data to the field positive prior to exposure (Schultz 1952).

COLORS

Kuchler (1967) suggested that when an author must decide on a color scheme for a new vegetation map, he will find it wise to study first the use of patterns, colors, and symbols on other vegetation maps. He found the method of using letters or numbers to distinguish different types of vegetation permits the production of vegetation maps at a low cost. The black color is used for everything: vegetation boundaries, symbols, grid, frame, title, legend, etc., and hence only one plate is required for printing. The chief disadvantage of this method, Kuchler (1967) found, is that it fails to show at a glance the distribution of the various vegetation types. He suggested the selection of light colors, as they are usually more pleasing, make the map more legible, and are especially useful in connection with overprinted symbols. However, if the number of colors on a map is large, it becomes difficult to distinguish between them, especially when the eye must go back and forth between the legend and the map. Kuchler (1967) warned that the overprinting of black symbols on black-and-white patterns should be avoided because the reader finds it difficult to read and hence to use such a map; but, on a colored map, symbols may be black or in color. Black symbols are difficult to see on dark colors, and colored symbols are not easily distinguished from surrounding colors if the color contrast is weak. He concluded that the clarity and legibility of a vegetation map are directly dependent upon the symbols, patterns, and colors that are used on the map.

BOUNDARIES

The technical problems of vegetation boundaries consist above all in deciding how the boundaries are to be shown on the map (Kuchler 1967). He stated: "Boundary lines have the advantage of making a map clear and of permitting precision to a very considerable degree. But some authors object to the sharp contrast between vegetation types produced by continuous lines as being unrealistic; therefore they omit boundary lines altogether. The contrast between different colors or patterns is considered adequate to offset one vegetation type from another whereas the sharp lines are felt to exaggerate the differences."

Transition types are likely to cause the greatest difficulty and have usually been neglected in cover mapping, yet they often are the most important elements from the standpoint of animal life (Graham 1945). Kuchler (1967) indicated the transition zone should certainly be shown if it is very wide, considering the scale of the map. He felt that where it is narrow, it may in some instances be ignored. Graham (1945) felt that narrow strips along streams may seem too insignificant to map, even though the existence of some animals may depend upon such a strip. Under his system of mapping, transition zones can be shown even when so narrow as to be indicated only by a line. Inserting the proper symbol (at a break in the line) will indicate clearly the existing conditions.

In the case of an invasion, the use of arrows can be quite effective (Kuchler 1967). The arrows are shown in the color of the invading community and are overprinted on the invaded one. The shape of the arrows is related to the degree of success of the invasion, thus: broad arrows imply a massive invasion; slender arrows an invasion of modest success at least up to the time of mapping; and the length of the arrows shows the depth of penetration.

ORGANIZATION OF MAP CONTENTS

TERMINOLOGY

A complete vegetation map, Kuchler (1967) felt, should include the following: title, legend, frame, scale, name of author(s), and year or years prepared.

A clear and unequivocal terminology is imperative on vegetation maps. Kuchler (1967) stated: "A vigorous (sic) organization requires a set of terms each of which produces the desired picture in the mind of the reader. Strictness in terminology is even more necessary than in organization because a poorly organized map makes reading difficult whereas poorly chosen terms may prevent any appreciation of the information which the author wishes to convey to his readers." He suggested that this attention to the quality of terms must not be limited to the legend items. It must be focused on all terms used anywhere on the map.

Wilson and Berard (1952) found the value of the complete map can be considerably increased by including three small inset maps showing soil types, drainage basins, and topography. Jahn (1969) pointed out that soil maps and reports are of little use for delineating specific wetlands (20 acres or less).

PROOFREADING

"To err is human—even the most careful mapper cannot avoid making mistakes. All vegetative maps must therefore be proofread; however, authors are warned that proofreading a vegetation map is very different from proofreading an article. Therefore, proofreading should be done at least twice. It is always best to have the proofreading done by more than one person. Everything must be proofread: the colors, the patterns, the symbols, the boundaries and their location, the title, the scale, the legend, etc. If the legend items are numbered and the numbers are repeated on the map, then the numbers must be proofread, too." Kuchler (1967).

MANAGEMENT IMPLICATIONS

The distribution of habitat and its relative quality and abundance have a profound effect on where and when waterfowl occur (Seamans et al. 1963), and its management is vital to meet the objectives of flyway management. Basically, Shaw and Fredine (1956) recognized three components of waterfowl habitats—water, food, and cover. Public refuges are developed and managed to produce the maximum of these three essentials from each acre. Because of the quality of the vegetation, both aquatic and upland, refuge management is largely plant management (Shaw and Fredine 1956). They felt that waterfowl utilization of a refuge — the only true measure of its value — is directly related to the abundance and availability of desirable food and cover plants. Waterfowl management is becoming increasingly intensive as it becomes necessary to satisfy ever greater human recreational requirements and integrate with changing habitat conditions (Seamans et al. 1963). They concluded that to meet present needs and those of the foreseeable future, habitat management must become more specific, developing or utilizing rather exacting techniques.

Mosby (1963) stated that cover maps are extremely useful for assessing general habitat conditions. If the cover-mapping technique utilizes the ecological approach, Mosby (1963) found that such maps can be projected for a period of years to give the wildlife investigator a better understanding of current habitat conditions and of those likely to prevail some years in the future. Conversely, if the cover-mapping technique does not utilize the ecological approach, the value of the map is limited to a comparatively short period of years.

In developing a habitat map the wildlife manager becomes well acquainted with the area. When he finishes, he will have a map and much data on the topography, drainage, soils, vegetation, and water (Alexander 1959).

Vegetation maps, when accompanied by contour maps, may be used for development planning in managed areas to control vegetation. Shaw and Fredine (1956) suggested that by proper manipulation of water levels, plant successions may be controlled to obtain the maximum yields of desirable plants. They state that other marsh management techniques used to control weed plants and to improve the value of desirable plants are controlled burning, use of herbicides, and removal of undesirable plants by mechanical means. The muskrat, properly managed, helps to create open water areas in dense cattail marshes (Shaw and Fredine 1956), and such openings can be located by mapping. Vegetation maps may be used to show areas of emergent vegetation die-off described by McDonald (1955), or show areas in need of, or the results of, undesirable plant control, described by Uhler (1944).

Uhler stated that, before any plant control operations are attempted, careful thought should be given to the probable effect on adjacent areas and to the possible biological repercussions within the control unit resulting from changes made. Along this same line, vegetation maps would be of great value as land-use changes on areas outside the management units. Plant species and their distribution may be used as indicators of change in quality of water entering the areas. To aid in this, Thorley (1968) used Ektachrome infrared photography to provide an index of siltation in streams, to map the extent and type of floating aquatic plants in lakes, and to detect the presence of algal blooms in reservoirs. This information is important for the determination of water quality, and the suitability of a lake for waterfowl inhabitation . . . (Thorley 1968).

Thus, aerial photographs permit a wildlife manager or ecologist to understand the composition, density, and distribution of wildlife cover; the depth or water quality of a lake or stream; the extent of erosion and siltation; the type and amount of pollution; and other characteristics of the environment in relation to fish and wildlife (Leedy 1968).

Alexander (1959) found that values received from habitat maps in wildlife management were continuous, serving throughout as a basis for management. If maintained, maps re[illegible] habitat changes and the results of managemen[illegible] stressed that attempting management without [illegible] is poor planning.

Kuchler (1953a) concluded that vegetation maps are not a panacea for all land-use problems. However, he felt that as more knowledge is accumulated concerning the preferences, requirements, and tolerances of plants and plant communities, it becomes easier to exploit a vegetation map to capacity; and as our knowledge of the indicator value of plant communities grows and deepens, the interpretation of a vegetation map becomes more efficient.

SUMMARY

Increased demands are being made on waterfowl resources and their habitat as the human population continues to grow. Recreation, industrial and agricultural development, and water pollution give extreme urgency to the protection and development of existing wetland areas. New and improved methods of management are needed if such areas are to reach maximum production.

There is an expressed need for vegetative mapping in wildlife management, whether upland or wetland. This technique, however, is little used by wildlife researchers or managers. Phytogeographers and foresters have led the way in the use of vegetation maps, although most of their work is of small scale. Large-scale mapping is necessary for purposes of research and intensive management.

Vegetation maps, when accompanied by soil and topographic information, give land managers an excellent tool with which to form development plans and foresee changes which may occur naturally. A vegetative classification system based on ecological succession, despite some confusion otherwise; is the best for management purposes. Prospective mappers should consult systems already proposed by various authorities rather than devise new systems of their own. Then and only then will maps of different areas be comparable.

Technological advances in aerial photography have greatly increased the precision and reduced the time required for vegetative mapping. It is now faster and more economical, in the final analysis, to use aerial photographs than to do field mapping without them.

A properly prepared vegetation map gives rapid visual information about an area and increases greatly the awareness of problems which may arise. The development of wildlife management practices for land areas, upland or wetland, without vegetation mapping is poor planning.

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